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㊵ Multiple position digital actuator end method of digitelly controlling a multiple position actuator element.

㊸ Multiple position digital actuator (28) particularly
adepted to control a plurality of bleed eir valves of a gas
turbine engine by converting 2^n n-bit digital control words
into 2^n physical positions of an actuator element (32), said
actuator (28) comprising: n pilot solenoids (110, 112, 114)
which are each associated with one of the bits of the digital
control words and which respectively control n three-way
valves (91, 93, 95), each having a first port in communication
with a pressure source (34) and a second port in communi-
cation with the return side of said pressure source (34); and
n telescoping piston-cylinder assemblies (32, 144, 156, 176),
each defining an expansible chamber (154; 168; 172) which
is in communication with the third port of a respective one
of the three-way valves (91, 93, 95), each of the expansible
chambers (154, 168, 172) being independently expended or
contracted to move the actuator element (32) under the
control of an associated set of pilot solenoid and three-way
valve according to the state of the bit eppiied to said pilot
solenoid, and the distance moved by the actuator element
(32) for adjacent piston-cylinder assemblies being in
ascending powers of two (2^0d, 2^1d, 2^2d).
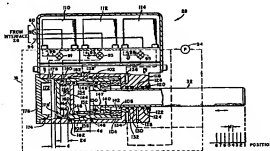
Multiple position digital actuator and method of digitally
controlling a multiple position actuator element

          The invention relates to a multiple position digi-
tal actuator for converting 2^n n-bit digital control words
into 2^n physical positions of an actuator element.
          For the regulation of the operation of many appa-
5   ratus today there is necessitated the physical positioning
of a control member according to a schedule or control law.
Usually, the mechanical positioning of the control member is
accomplished by an actuation device responding through an in-
terface to a control signal calculated by a controller. In-
10 creasingly, the control signal will be calculated by a con-
troller including a digital electronic processor which will
regulate the positioning of the actuator as a function of di-
gital control words. Heretofore, the conversion of the infor-
mation contained in the digital control words into physical
15 positions has not been efficiently performed by conventional
actuators.
          Generally, either a digital-to-analog converter has
been needed to control an analog actuator system positioning
itself with respect to the analog signal or each bit of the
20 digital control words has been used to control an associated
binary actuator determining a separate position. The former
method is quite complex and requires relatively expensive
actuators or stepper motors while the latter method is power
consuming and increases the weight of the whole system. Nei-
25 ther actuator technique is entirely satisfactory for the
sophisticated digital control systems being developed for
future utilization.
          More specifically, the control of the operation of
combustion engines based on their operating parameters may
30 require many multipositional actuators. For example, to con-
trol a combustion engine of the gas turbine type an electro-
nic controller has been used to control actuators for the
bleed air valves of the compressor, the stator vane

-2-

positioning, the nozzle positioning, fuel control, and posi-
tioning of other control members. Additional control functions
may be envisioned for multipositional actuators in the future.

5   With respect to a particular application for a
multiposition actuator, the bleed air valves are a series of
valves used to vent the compressor of a gas turbine engine
when the air flow between adjacent stages is mismatched to
prevent the compressor from stalling. These valves are used
primarily for starting or other operational sequences where
10 one or more of the series is opened to regulate the quantity
of air being supplied to the final compressor stages. The air
bleed valves have also been used to provide a supply of pressu-
rized air to other areas of the engine system.

      Previously, each air bleed valve has been controlled
15 by an individual solenoid. These solenoids were controlled by
digital words where one bit was assigned to each valve. The
presence of a bit 1 in the control word would actuate a parti-
cular air bleed and the absence of a bit 1 would close it.
However, this system mandates that each solenoid will be large
20 or mechanically powerful enough to perform the task assigned.
Since the solenoid valves work against compressor pressure
they have been by necessity relatively heavy. The excess
weight of these valves in gas turbine engine systems for air-
craft is viewed critically.

25   Moreover, the use of these large solenoids requires
that a separate driver circuit be used for each one. The logic
levels developed digitally have to be transformed into power
levels sufficiently to drive the large solenoids. These drivers
consume considerable amounts of power which must be generated
30 onboard in aircraft. The increased weight for aircraft of the
electric generation devices used to create this excess power
is also undesirable.

      The present invention overcomes the limitations and
disadvantages of the prior art arrangements by providing a
35 multiple position digital actuator for converting 2^n n-bit
digital control words into 2^n physical positions of an
actuator element, comprising: n piston-cylinder combinations,
each of said combinations being operable to move the actuator
element independently of the other combinations through a

respective distance controlled by an expansible chamber dis-
posed between the piston and cylinder of each of said combi-
nations, each of the distances being related to the other
distances by powers of two; and n pilot solenoids, each being
5 associated with an expansible chamber and operable to control
means for communicating pressure from a pressure source to a
corresponding chamber or from said corresponding chamber to
the pressure return side of the pressure source thereby cau-
sing expansion or contraction of the chamber and movement of
10 the actuator element, and each of the pilot solenoids being
associated with one of the bits of the digital control words
and actuated by one of the states of said one bit.

       A number of distinct advantages are obtained from
an actuator constructed in this manner. In aircraft applica-
15 tions one important advantage is weight savings when used in
an air-bleed control system. The individual large solenoids of
the previous systems are replaced by much lighter pilot val-
ves.

       Additionally, the driver circuits which were used
20 to transform logic level signals into control level signals
can be eliminated or drastically reduced. The pilot solenoids
consume much less power and if judiciously chosen can be run
directly from the output ports of a microprocessor or logic
circuitry. This feature represents not only a circuitry
25 savings but an electrical power capacity reduction for an
aircraft electrical generator system which translates direct-
ly into a weight savings.

       The weight savings can be considerable because the
invention takes advantage of the mechanical force amplification
30 available by controlling a pressure source with the piston-
cylinder combinations. This amplification can be obtained rea-
dily without sacrifice in particular applications because many
engines already include fluid power sources having excess capacities.
Thus, the actuator can use small pilot solenoids to produce
35 large mechanical forces. In aircraft or other applications
using a gas turbine engine the compressor airflow or a star-
ter motor airflow can be utilized for this function.

       One way of carrying out the invention is described
in detail below with reference to the drawings which illustrate

-4-

one embodiment of the invention, in which:

FIGURE 1 is a schematic block diagram illustrating
an air bleed control system for a gas turbine engine utili-
zing a multiple position digital actuator constructed in
accordance with the invention;

FIGURE 2 is a partially cross-sectional side view
of the actuator used in the system illustrated in FIGURE 1;
and

FIGURE 3 is an actuation table illustrative of the
translation of digital control words into physical positions
of the actuator.

With reference now to FIGURE 1, there is shown an
air bleed control system for a turbo-jet engine utilizing a
multiple position digital actuator constructed in accordance
with the invention. The turbo-jet engine generally designated
as 10 includes an air inlet 12, a low pressure compressor
section 14, a high pressure compressor section 15, a burner
section 16, a turbine section 18, an exhaust nozzle 20, and
an afterburner 22. Air drawn through the inlet 12 is compres-
sed by the two compressor sections 14 and 15 and when fuel is
injected into the burner section 16, a highly energetic bur-
ning gas is exhausted through nozzle 20 to be reburned in
afterburner 22. As is known, the reaction of the engine to
the exhaust gas is a forward thrust used for motive power.
The turbine section 18 drives the compressor sections 14,15
by consuming a portion of the exhaust gas energy before it
exits the nozzle 20. Inasmuch as this invention is not pri-
marily concerned with the reaction engine, and its parts are
conventional, it will not be more fully described.

Between the stages of the high pressure compressor
section 15 is located a plurality of air bleed valves in an
assembly 30. These valves are used to vent the pressurized
air from the stages of the low pressure compressor section
14 before it is input to the stages of the high pressure com-
pressor section 15. It is known that these may be used for
starting, other bleed sequences, or for powering other
auxiliary devices in an aircraft. Such other auxiliary devices
include anti-icing mechanisms or boundary layer controls.

The assembly 30 for the actuation of the air bleed

valves comprises a tubular actuator piston or element 32
from a multiple position digital actuator 28. The actuator
28 is connected to an electronic controller 24 through an
interface circuit 26. The interface circuit 26, for example,
if the controller 24 is a microprocessor, would preferably
be the microprocessor output ports.

The controller 24 if scheduling a starting sequence
will have as an input the speed signal $N\ell$ from the low pres-
sure compressor section 14 and the speed signal Nh from the
high pressure compressor section 15. Noting the differences
between these two input signals will allow the controller to
schedule an output to the interface circuit 26 in the form
of a three-bit digital word. It is readily apparent that
other inputs may be provided to the controller 24 for sche-
duling the auxiliary devices or for different sequencing
during startup or other control. Other engine parameters that
may be useful in air bleed control are temperatures and
pressures of the turbine and compressor sections.

Power for the multiple position digital actuator 28
is obtained from a pressure source 34 which can alternatively
be supplied from a tap of the compressor sections of the
engine or from a pressure source such as an air starter motor
or the like. Other sources of fluid pressure that are readily
available may also be used. Pressure sources found in a gas
turbine engine system include high pressure fuel and hydrau-
lic pumps or the like.

The actuator 28 receives the digital word and con-
verts it directly into a position of the actuator piston 32
by a piston-cylinder assembly which will be more fully des-
cribed hereinafter. The number of positions of the actuator
piston 32 is related to the number of digital control words.
In the present example, the digital control words have three
bits and, therefore, the actuator piston 32 will have eight
discrete physical positions.

The actuator 28 will now be more fully explained
with reference to FIGURE 2. The actuator 28 comprises three
pilot solenoids 110, 112 and 114, respectively, which are
adapted to receive the digital input signal or control word
and position the actuator piston 32 with respect to the

value of that input signal. There are three solenoids present, each associated with one bit of the digital control word, and there are 2^n or eight positions available for the actuator piston 32. Assuming one position will be taken to signify

5 that all the air bleed valves are closed, there will then be seven positions remaining, one to correspond to the opening of each air bleed valve or the extent of opening of the valve.

The coils of the solenoids 110, 112, and 114 are con-
nected via signal lines 90, 92, and 94, respectively, to the

10 controller 24 through interface 26. A high voltage level on a signal line, representing that a bit 1 is present in the digi-
tal control word for that bit position, will energize the coil and actuate a three-way valve of the solenoid. The sole-
noids, for example, solenoid 110, upon energization will vent

15 a pressure port 178 via vent 96 through a valve 91. Upon de-
energization the pressure port 178 will be connected through the valve 91 to pressure source 34. Similarly, solenoids 112, 114, actuate valves 93 and 95, respectively, to connect pres-
sure ports 180, 182, to vents 97, 98. When deactivated the

20 valves 93, 95 will communicate pressure ports 180, 182 to the pressure source 34. The vents 96, 97, 98 are connected to return fluid back to the pressure source 34 through a re-
turn conduit 36.

Therefore, a high voltage level in a bit position

25 for a corresponding solenoid will vent a pressure port and a low voltage level will pressurize it. This method will trans-
form the digital electrical signal at signal lines 90, 92, and 94 into a fluidic pressure signal of a binary nature at the ports 178, 180, and 182. The fluidic signal is subsequen-

30 ly further transformed into mechanical actuation motion by a piston-cylinder assembly to linearly move actuator piston 32 through its eight positions.

Each of the solenoids 110, 112, and 114 is prefera-
bly a conventional low power solenoid that can be energized

35 without a large power consumption or complex driving circui-
try. Advantageously, the solenoids can be operated directly from the digital gate levels of the controller 24 such as those found on the output ports of a microprocessor or the

like. Normally, these gate levels are between 5 volts and 15
volts for a digital control system.

    The pressure source 34 in combination with the pis-
ton-cylinder assembly then provides the needed force amplifi-
5 cation for the movement of the actuator piston 32 against the
pressure of the compressor. As the actuator is depicted in
FIGURE 2, the actuator piston 32 is at its furtherest right-
ward limit and will move in seven more equal increments of
distance $\underline{d}$ to the left upon actuation by the digital control
10 word. An actuation table, labeled FIGURE 3, describes the cor-
respondence between the values of the digital control words
and the actuator piston positions.

    The actuator piston 32 is essentially an elongated
actuation element of a hollow tubular shape connected integral-
15 ly to a piston-shaped flange 147 at its actuation end. The
piston extends through an aperture formed in a base 118 of
the actuator 28. The piston 32 is sealed hydraulically by
dual rings 130 and 132 of suitable material compressed be-
tween the actuation piston and a set of grooves cut in the
20 aperture of the base 118. Even with these dual rings a weep
ring 126 has been cut in the aperture to drain the fluid
pressure which escapes. The weep ring 126 communicates to a
weep port 128 which returns the escaped fluid to low pressure
return of the pressure source 34 via a suitable conduit.

25   Another ring 124 of lesser sealing capability is
compressed between the actuator piston 32 and a groove cut
in the aperture to provide a final seal for the actuator pis-
ton 32. To lubricate the actuation piston 32 an oil-impregna-
ted packing material 122 is provided in a step cut in the
30 aperture of the base 118. Packing material 122 is retained in
the step by a face washer 120 that fits against the base 118.

    The flange 147 of the actuator piston 32 is teles-
coped into a generally cylindrically shaped first cylinder 144.
The first cylinder is closed at one end and open at the other.
35 The first cylinder 144 retains the flange 147 of the actuator
piston 32 by the means of a centrally bored first annular nut
140 being screwed onto a threaded portion at its open end.
The actuator piston 32 extends through the center bore of the
first nut 140 and is free to move reciprocally depending on

the movement of the flange 147. Fluid pressure communication
is prevented between the open end of the first cylinder 144
and the closed end thereof by a ring 150 compressed in a groove
cut circumferentially around the flange 147. The flange 147 is
5 operable to move between the closed end of the first cylinder
144 and a position where it is stopped by abutment against the
first nut 140.

        The first cylinder 144 and actuator piston 32 form
a first piston-cylinder assembly which is telescoped into an-
10 other generally cylindrical second cylinder 156. As is the
first cylinder 144, the second cylinder 156 is closed at one
end and open at the other. The second cylinder 156 retains
the first piston-cylinder assembly by a centrally bored second
annular nut 142 screwed onto a threaded portion at the open end
15 thereof. The actuator piston 32 additionally extends through
the center bore of the second nut 142 and is free to move reci-
procally depending upon the movement of the first piston-cylin-
der assembly. Fluid pressure communication is prevented between
the open end of the second cylinder 156 and the closed end
20 thereof by a set of rings 152, 160 compressed in grooves cut
circumferentially around the first cylinder 144. A first auxi-
liary chamber 102 is defined by notch machined around the out-
side wall of the first cylinder 144 and the inside wall of the
second cylinder 156. The first auxiliary chamber 102 is also
25 isolated from fluid communication by rings 152, 160. The first
piston-cylinder assembly is operable to move between the clo-
sed end of the second cylinder 156 and a position where it is
stopped by abutment against the second nut 142.

        The assembly of the first piston-cylinder assembly
30 and the second cylinder 156, forming a second piston-cylinder
assembly, is mounted within a generally cylindrical base cavi-
ty 104 in the base 118. The base cavity 104 is open at one
end and closed at the other end. The cavity is sealed at its
open end by an end cap 176 and a ring 174 compressed in a groove
35 cut circumferentially therein. The actuator piston 32 is free
to move reciprocally with respect to the base cavity 104
depending upon the movement of the second piston-cylinder as-
sembly. Three rings 148, 162, and 178' block fluid communica-
tion between the closed end and open end of the base cavity

-9-

104. In addition, the ring set 148, 162 prevent fluid communication to and from a second auxiliary chamber 108 formed from a notch machined around the inside wall of the base cavity 104 and the outside wall of the second cylinder 156.
5   Still further, the ring set 162, 178' prevents fluid communication to and from a third auxiliary chamber 164 defined by a groove cut in the outside wall of the second cylinder 156. The second piston-cylinder assembly is operable to move between the closed end of the base cavity 104 and a posi-
10   tion where it is stopped by abutment against the end cap 176.

The telescoping assembly of pistons and cylinders described, separates the base cavity 104 into a number of expansible and contractable pressure chambers. A variable volume pressure chamber 154 is defined by the inner wall of
15   the first cylinder 144 and the flange 147 of the actuator piston 32. Another variable volume pressure chamber 168 is defined between the inside wall of the second cylinder 156 and the closed end of the first cylinder 144. A third variable volume chamber 172 is defined by the end cap 176 and
20   the closed end of the second cylinder 156. Each of the variable volume pressure chambers may have its volume changed by reciprocation of the respective telescoping elements defining its boundaries. Specifically: actuator piston 32 reciprocates in the first cylinder 144 to change the volume of chamber 154;
25   the first piston-cylinder assembly 144, 32 reciprocates in the second cylinder 156 to change the volume of the pressure chamber 168; and the second piston-cylinder assembly 144, 32, 156 reciprocates in the base cavity 104 to change the volume of the pressure chamber 172.

30   Each variable volume chamber is associated with an individual pressure port. Specifically, pressure port 178 communicates directly with chamber 172 while pressure ports 180 and 182 communicates through the auxiliary pressure chambers to chambers 168 and 154, respectively. Pressure port 180
35   communicates initially to the third auxiliary chamber 164 and then to chamber 168 via vents 166, 166'. Similarly, pressure port 182 communicates via the first and second auxiliary chambers 102, 108 to chamber 154. Initially, pressure port 182 communicates with the second auxiliary chamber 108 and

it with the first auxiliary chamber 102 through fluidic
connection by apertures 158, 158'. The first auxiliary
chamber 102 then communicates with chamber 154 via vents
146, 146'. Accordingly, it may be said that each of the
pressure ports 178, 180, 182 communicates with an associa-
ted one of the expansible chambers 154, 168, 172 by a number
of auxiliary chambers 102, 108, 164, if any, which number
is dictated by the power of two represented by the ordinal
number of the expansible chamber minus one. For example:
for the 1st expansible chamber 172, the power of two is
$2^{1-1}= 2^0$, thus there are no auxiliary chambers; for the 2nd
expansible chamber 168, the power of two is $2^{2-1}=2^1$, thus
there is one auxiliary chamber 164; and for the 3rd expan-
sible chamber 154, the power of two is $2^{3-1}=2^2$, thus there
are two auxiliary chambers 102, 108.

Consequently, the pressure chambers are, because
of their association with individual pressure ports, each
associated with an individual signal line and, therefore, an
individual bit of the incoming signal. A high level on a
signal line, indicating the presence of a bit 1, will vent
the respective chamber and a low level on the signal line,
indicating the absence of a bit 1, will pressurize the
chamber.

Pressure ports 134 and 136 are provided to supply
a bias chamber 106 with fluid pressure from the pressure
source 34. The bias chamber 106 is formed by that part of
the base cavity 104 between ring 148 and the closed end of the
base cavity 104. Pressure in this chamber causes movement of
the piston-cylinder assemblies when the expansible chambers
154, 168, and 172 are vented. Movement by the piston-cylinder
assemblies in the other direction is caused by the force un-
balance because of the differing areas over which the pres-
sure source operates.

In operation, the actuator piston 32 moves to
positions 1 through 8 by venting or pressurizing combinations
of the chambers 154, 168, 172, according to presence or
absence of bits 1 in the digital control word. Energizing
solenoid 110 causes the second cylinder 156 to move a dis-
tance d and thereby move the actuator piston 32 an identical

distance. Energizing solenoid 112 causes the first cylinder 144 to move a distance 2d and thereby move the actuator piston 32 an identical distance. Finally, energizing solenoid 114 causes the actuator piston 32 to move a distance of 4d.

5   Thus, the movement of the actuator piston 32 caused by individual solenoids is independent of the others but related to its bit position by a power of two. It is evident that combinations of these movements will then produce movements corresponding to the actuation table shown in FIGURE 3.

10   While the preferred embodiments of the invention have been shown and described, it will be obvious to those skilled in the art that various modifications and changes may be made thereto. For example, the pressure source 34 has been described as an air pressure source. It would be obvious

15   to provide any other type of fluid pressure source, vacuum or above ambient, to power the piston-cylinder assemblies. It is recognized that what is necessitated by the invention is a difference in pressures between the chambers to operate the actuator piston. As a consequence, the actuator piston

20   may be operated in the sequence described hereinbefore where it moves from right to left as combinations of chambers are vented or it could just as easily move from left to right by pressurizing combinations of chambers. It is also well within the ordinary skill of the art to expand or reduce the

25   invention to any force or size desired. An expansion or reduction of the invention may also be consummated with respect to the size of the digital control words and number of actuation positions. Additional piston-cylinder assemblies and pilot solenoids can be added to adapt the invention to any

30   size of digital control words.

Claims:

1. A multiple position digital actuator (28) for converting 2^n n-bit digital control words into 2^n physical positions of an actuator element (32), characterized in that it comprises: n piston-cylinder combinations (32,144,156,176), each of said combinations (32-176) being operable to move said actuator element (32) independently of the other combinations through a respective distance controlled by an expansible chamber (154; 168; 172) disposed between the piston and cylinder of each of said combinations (32-176), each of the distances ($d,2d,4d$) being related to the other distances by powers of two; and n pilot solenoids (110,112,114), each being associated with an expansible chamber (154;168;172) and operable to control means (91;93;95) for communicating pressure from a pressure source (34) to a corresponding chamber or from said corresponding chamber to the pressure return side of said pressure source (34) thereby causing expansion or contraction of the chamber and movement of said actuator element (32), and each of said pilot solenoids (110,112,114) being associated with one of the bits of said digital control words and actuated by one of the states of said one bit.

2. A multiple position digital actuator as claimed in Claim 1, characterized in that said n piston-cylinder combinations (32-76) are telescoped within each other such that the distance moved by the actuator element (32) for adjacent combinations is in ascending powers of two ($2^0d,2^1d,2^2d$).

3. A multiple position digital actuator as claimed in Claim 1, characterized in that said n piston-cylinder combinations (32-76) are telescoped within each other such that the distance moved by the actuator element (32) for adjacent combinations is in descending powers of two ($2^2d,2^1d,2^0d$).

4. A multiple position digital actuator as claimed in Claim 1, characterized in that said actuator element (32) comprises an elongated body with a flange (147) on one end, said flange (147) acting as a piston and being disposed within a first cylinder (144) of the n piston-cylinder combinations (32-76).

5. A multiple position digital actuator as claimed
in Claim 4, characterized in that there is provided means
(34,106) for generating a force opposing movement of said
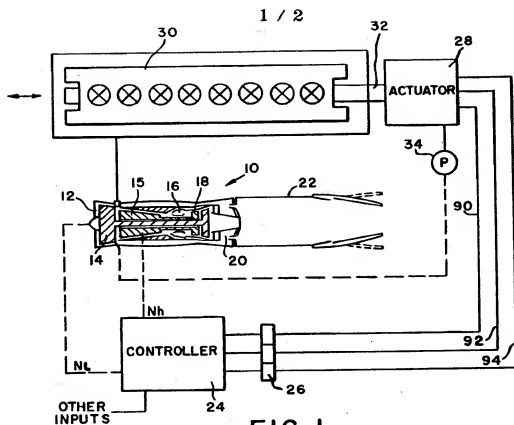actuator element (32) in one direction.

6. A multiple position digital actuator as claimed
in Claim 5, characterized in that there are provided n pres-
sure ports (178,180,182), each associated with and control-
led by one of said n pilot solenoids (110,112,114), for pressu-
rizing said expansible chambers (154,168,172).

7. A multiple position digital actuator as claimed
in Claim 6, characterized in that each of said pressure ports
(178,180,182) communicates with an associated one of said expan-
sible chambers (154,168,172) by a number of auxiliary cham-
bers (164;102,108), if any, which number is dictated by
the power of two represented by the ordinal number of the
expansible chamber minus one.

8. A multiple position digital actuator as claimed
in Claim 1, characterized in that said pressure source (34)
is a compressed air source.

9. A multiple position digital actuator as claimed
in Claim 1, characterized in that said pressure source (34)
is a vacuum air source.

10. A method of digitally controlling a multiple
position actuator element (32), characterized in that it
comprises the steps of: generating 2^n n-bit digital electri-
cal signals representative of the 2^n physical positions of
the actuator element (32); converting the individual n-bit
electrical signals into corresponding individual n-bit flui-
dic signals; and converting said individual n-bit fluidic
signals by means of n piston-cylinder assemblies (32,144,
156,176) into individual position signals acting upon the
actuator element (32) to cause it to be moved to the 2^n phy-
sical positions corresponding to the 2^n n-bit digital elec-
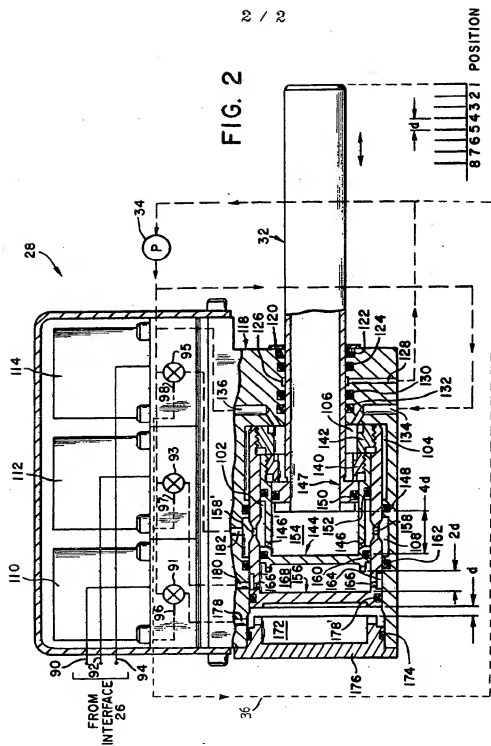trical signals.

FIG. I

ACTUATION TABLE

SOLENOID 114	SOLENOID 112	SOLENOID 110	POSITION
O	O	O	1
O	O	I	2
O	I	O	3
O	I	I	4
I	O	O	5
I	O	I	6
I	I	O	7
I	I	I	8

FIG. 3

0045228

FIG. 2

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim
X	CH - A - 407 759 (SCHWEIZERISCHE LOKOMOTIV- UND MASCHINENFABRIK) * Entire document * --	1-8,10
X	GB - A - 1 007 633 (SPERRY GYROSCOPE) * Entire document * --	1-7
X	US - A - 3 114 296 (SMITH) * Entire document * ----	1-7

CLASSIFICATION OF THE
APPLICATION (Int. Cl.³)

F 15 B 11/12

TECHNICAL FIELDS
SEARCHED (Int. Cl.³)

F 15 B

CATEGORY OF
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X: particularly relevant
A: technological background
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P: intermediate document
T: theory or principle underlying
   the invention
E: conflicting application
D: document cited in the
   application
L: citation for other reasons

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   family,
   corresponding document

The present search report has been drawn up for all claims		
Place of search The Hague	Date of completion of the search 14-10-1981	Examiner KNOPS

EPO Form 1503.1 06.78